Electronic Version

Stylesheet Version v1.1.1

Claims

[c1] A method for determining a desired anisotropy axis angle for a magnetic random access memory (MRAM) device, the method comprising:
selecting a plurality of initial values for the anisotropy axis angle;
determining, for each selected initial value of the anisotropy axis angle, a minimum thickness for at least one ferromagnetic layer of the MRAM device, wherein said minimum thickness corresponds to a predefined activation energy of an individual cell within the MRAM device;
determining, for each selected value of the anisotropy axis angle, a minimum applied magnetic field value in a wordline direction and a bitline direction of the MRAM device so as maintain said predefined activation energy; and
calculating, for each selected value of the anisotropy axis angle, an applied power per bit value;
wherein the desired anisotropy axis angle is the selected anisotropy axis angle corresponding to a minimum power per bit value.

[c2] The method of claim 1, wherein said power per bit value for a given selected anisotropy axis angle is calculated from said minimum applied magnetic field value in said wordline and bitline directions associated therewith.

[c3] The method of claim 2, wherein said power per bit value is further calculated from an efficiency factor between wordlines and bitlines of the MRAM device.

[c4] The method of claim 3, wherein said minimum thickness and said minimum applied magnetic field value in said wordline and bitline directions are determined as a function of said selected value of the anisotropy axis angle through a set of universal curves.

[c5] The method of claim 3, wherein the desired anisotropy axis is configured for rotational switching of the MRAM device.

[c6] The method of claim 1, further comprising:
establishing a maximum desired thickness for said at least one ferromagnetic layer of the MRAM device; and
wherein the desired anisotropy axis angle is the selected anisotropy axis angle corresponding to a minimum power per bit value for a thickness less than or equal to said maximum desired thickness for said at least one ferromagnetic layer of the MRAM device.

[c7] A magnetic random access memory (MRAM) device configured for rotational switching of an anisotropy axis associated therewith, comprising:
a wordline;
a bitline;
a storage element disposed between said wordline and said bitline, said storage element further comprising a reference magnetic layer stack and a free magnetic layer stack; and
said free magnetic layer stack is formed so have an anisotropy axis angle with respect to axes defined by said wordline and said bitline, wherein said anisotropy axis angle is further oriented so as to facilitate a minimum power per bit dissipation for the device.

[c8] The MRAM device of claim 7, wherein said anisotropy axis angle is based on an efficiency factor between said wordline and said bitline.

[c9] The MRAM device of claim 8, wherein:
said wordline is disposed in a direction orthogonal to said bitline; and
said anisotropy axis angle is a non-45° angle with respect to said axes defined by said wordline and said bitline.

[c10] The MRAM device of claim 8, wherein said free magnetic layer stack further comprises a pair of ferromagnetic layers separated by a non-ferromagnetic spacer.

[c11] The MRAM device of claim 7, wherein said efficiency factor is greater than 1.

[c12] The MRAM device of claim 11, wherein said efficiency factor is determined by a difference in field generating efficiency between said wordline and said bitline.

[c13] The MRAM device of claim 11, wherein said efficiency factor is determined by a number of bits, N that are written by said wordline, wherein N is greater than 1.

[c14] The MRAM device of claim 7, wherein said anisotropy axis angle is further oriented so as to facilitate a minimum power per bit dissipation corresponding to a thickness of at least one ferromagnetic layer of said free magnetic layer stack that is less than or equal to a maximum desired thickness thereof.

[c15] A magnetic random access memory (MRAM) device, comprising:
a plurality of wordlines;
a plurality of bitlines;
a plurality of storage elements disposed between said wordlines and said bitlines at corresponding intersec-

tions thereof, each of said plurality of storage elements further comprising a reference magnetic layer stack and a free magnetic layer stack; and
said free magnetic layer stack is formed so have an anisotropy axis angle with respect to axes defined by said wordlines and said bitlines, wherein said anisotropy axis angle is further oriented so as to facilitate a minimum power per bit dissipation for the device.

[c16] The MRAM device of claim 15, wherein said anisotropy axis angle is based on an efficiency factor between said wordlines and said bitlines.

[c17] The MRAM device of claim 16, wherein:
said wordlines are disposed in a direction orthogonal to said bitlines; and
said anisotropy axis angle is a non-45° angle with respect to said axes defined by said wordlines and said bitlines.

[c18] The MRAM device of claim 16, wherein said free magnetic layer stack further comprises a pair of ferromagnetic layers separated by a non-ferromagnetic spacer.

[c19] The MRAM device of claim 23, wherein said efficiency factor is greater than 1.

[c20] The MRAM device of claim 19, wherein said efficiency

factor is determined by a difference in field generating efficiency between said wordlines and said bitlines.

[c21] The MRAM device of claim 18, wherein said efficiency factor is determined by a number of bits, N that are written by said wordline, wherein N is greater than 1.

[c22] The MRAM device of claim 15, wherein said anisotropy axis angle is further oriented so as to facilitate a minimum power per bit dissipation corresponding to a thickness of at least one ferromagnetic layer of said free magnetic layer stack that is less than or equal to a maximum desired thickness thereof.